

TIGER PREY IN A TROPICAL DRY FOREST: AN ASSESSMENT OF ABUNDANCE AND OF BIOMASS ESTIMATION DERIVED FROM DISTANCE SAMPLING

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Data on animal and biomass densities of Tiger prey were collected using Distance Sampling in Panna Tiger Reserve, India. Line transect surveys for Distance Sampling were conducted in 2000, 2001, 2003 and 2005 using different approaches. Animal and biomass densities from 2003 are compared with estimates available from other reserves of the Indian subcontinent. In Panna Tiger Reserve density of Tiger prey is estimated to be 46.32 animals /sq. km. Chital, Nilgai and Sambar dominate the Tiger prey population of the Reserve. In terms of number of animals, Chital is the most abundant followed by Nilgai and Sambar; however, Nilgai groups are the most frequently encountered prey. The prey biomass density estimated for the Panna Tiger Reserve is 4,057 kg/sq. km. Most of the biomass is contributed by two prey species, Nilgai and Sambar. The biomass density contribution of Chital and smaller prey is small compared to other protected areas of the Subcontinent. In terms of the number of animals, contribution by large prey, medium prey and smaller prey is almost equal in Panna. But in comparison to other Tiger habitats the contribution by Chital and other medium prey in Panna Tiger Reserve is small, both in terms of the number of animals (39.24%) and of biomass density (21.26%). However density estimates from Panna Tiger Reserve and other protected areas indicate that Tropical Dry Forests, which are the largest Tiger habitat in the Subcontinent, can support fairly high prey populations and sustain a viable Tiger population. In tropical forests, where ecological conditions vary drastically, February and March appear to be the most suitable time for Distance Sampling. To minimise the errors encountered during the surveys, a short sampling period with more lines, which are walked only once a day and repeated after a few days, is suggested.

Key words: Tiger prey, ungulates, density estimation, line transect, Tropical Dry Forest, India

INTRODUCTION

The Tiger *Panthera tigris* occupies diverse habitats and preys mainly on large ungulates (Schaller 1967; Sunquist 1981; Johnsingh 1983; Seidensticker and McDougal 1993; Karanth and Sunquist 1995; Sunquist *et al.* 1999; Biswas and Sanker 2002; Bagchi *et al.* 2003). Its abundance is governed by the availability of its prey (Karanth *et al.* 2004; Sunquist and Sunquist 1989). Recent studies indicate that loss of prey is one of the major factors affecting the viability of the Tiger populations (Karanth and Stith 1999); they further indicate that a demographically viable Tiger population can be protected, provided that its prey base is managed intensively. Therefore, in order to save Tigers in the wild, effective management of large herbivore populations is a very important conservation issue in all Tiger habitats. The Tropical Dry Forest is the largest Tiger habitat in the Indian subcontinent, but very little quantitative information is available from this ecosystem. This Tiger habitat is highly fragmented (Wikramanayake *et al.* 1998) and suffers from forest fires, poaching, competition with livestock and loss of habitat and habitat quality (Panwar 1987; Karanth 1991; Debroy 1996; Seidensticker 1997; Chundawat *et al.* 1999; Chundawat and Gogate 2001). For effective

conservation measures to save Tigers in dry forests, intensive management of prey populations requires strategies to manage prey in densities that can support a demographically viable Tiger population.

Estimation of large herbivore populations in the wild has always been a very difficult task. In the past, various approaches were used which lacked robust theoretical and statistical basis (Schaller 1967; Eisenberg and Lockhart 1972; Tamang 1982; Johnsingh 1983). But, in the last decade, Distance Sampling using line transect surveys has been found very useful for estimating biological populations (Burnham *et al.* 1980; Buckland *et al.* 1993; Plumptre 2000; Anderson *et al.* 2001; Buckland *et al.* 2001; Marques *et al.* 2001). In India, Distance Sampling has been used widely in diverse forest habitats for estimation of ungulate populations (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Jathanna *et al.* 2003; Karanth *et al.* 2002; Bagchi *et al.* 2003). Different approaches employed for line surveys vary from walking transects every month to walking all lines simultaneously within a few weeks (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Bagchi *et al.* 2003). Inherent spatial and temporal variability during the sampling period can affect the precision of survey results (Thomas *et al.* 2002).

In this paper we provide information on abundance and biomass densities of Tiger prey from a tropical dry forest. In addition, the paper assesses and compares various approaches employed for estimating animal densities using line transects. We hope that these comparisons will be useful in designing future surveys to achieve better precision and reliability.

Data from these surveys are analysed to discuss the best approach and season for surveys in tropical forests, where visibility changes considerably with season and can thus affect density estimates. These data sets are also analysed to determine the efficiency of the survey without compromising assumptions. We have compared the seasonal encounter rates for “efficiency” (number of detections per km walk), detection functions and group size over time for heterogeneity. We also looked at the likely bias due to repeated visits on the same day possibly causing animal movement away from the transect line.

STUDY AREA

The Panna Tiger Reserve in central India encompasses 543 sq. km of tropical dry forest. The intensive fieldwork was carried out within approximately 350 sq. km of the Reserve. Extensive plateaux and gorges characterise the terrain of the area. Its unique step topography divides the area into the upper Talgaon and middle Hinauta plateaux and lower Ken river valley. The River Ken passes through the National Park and is the major perennial source of water. The plateaux are separated by 10-80 m high escarpments, creating several deep gorges at many places; these are characterised by steep rock faces, thick forest cover and series of caves at the base of escarpments. The average annual rainfall is 1,100 mm of which almost 60-70% falls during July and August. This is followed by a long dry spell continuing from October to June. Due to the hilly topography and long dry season, water is a major limiting factor during the summer months when temperature can regularly exceed 45 °C. There are 13 villages within the Reserve with a human and cattle population of 6,000 and 9,500, respectively.

The dominating vegetation type is “Dry Teak Forest” (C1-b, Champion and Seth 1968). The extensive dry and short grass habitats with open thorny woodlands support antelope populations of Nilgai *Boselaphus tragocamelus* and Chinkara *Gazella bennettii*. The more mesic habitats with tall grass and associated closed miscellaneous forest, mainly distributed along the major seasonal drainages, support high ungulate densities, including Sambar *Cervus unicolor*, Chital *Axis axis*, Wild Pig *Sus scrofa* and Four-horned Antelope *Tetracerus quadricornis*. The distribution of these habitats creates a diverse and very heterogeneous landscape, where ecological

conditions also vary seasonally. The Tiger Reserve supports a diverse carnivore population, which includes Tiger, Leopard *Panthera pardus*, Sloth Bear *Melursus ursinus*, Dhole *Cuon alpinus*, Grey Wolf *Canis lupus*, Striped Hyena *Hyaena hyaena*, Jungle Cat *Felis chaus* and Indian Fox *Vulpes bengalensis*.

METHODOLOGY

In this study we used Distance Sampling to estimate the abundance of Tiger prey in the Panna Tiger Reserve. Line transect surveys were conducted in 2000, 2001, 2003 and 2005. Nine line transects of variable length, ranging from 1.93 to 2.85 km, were marked and prepared for silent walking. These nine lines were placed randomly covering almost all the available habitat types in the intensive study area. Care was taken to not over-clear the line for it could have caused a spike at zero distance (animals using lines as walkways), which is hard to model (Buckland *et al.* 2001; Gangadharan 2005). These transects were walked between sunrise and 0930 hrs and between 1500 hrs and sunset. For every sighting of a group, information on species, number of individuals, radial distance (with the help of a laser range finder), and radial angle were recorded.

In 2000, these nine line transects were walked in the morning twice every month from October to June. Later, this approach was modified and in 2001, all the lines were walked simultaneously every morning and evening, for 15 days in March. Further modification was made in the 2003 survey: only three lines were walked simultaneously morning and evening, and these were repeated every fourth day in February and March. Thus, in total 24 (12 days x 2 times a day) temporal replicate surveys for each line were conducted. In 2005, to test the effect of repeated walks on the same day (19 field days), on density estimates, we walked the same line in the morning and later in the evening after a gap of more than two days. The exercise was done for 19 field days.

For analysis of data, the computer program DISTANCE 4.1 (Thomas *et al.* 2003) was used. Biomass densities of Tiger prey were calculated for each survey. Data from the survey of 2003 was used to compare estimates documented from other habitats of the Indian subcontinent.

Analysis:

We followed the standard procedures for analysis described in Buckland *et al.* (2001) and Thomas *et al.* (2003). For density estimates and related analyses concerning variance, the nine transect lines were considered as spatial replicates, and all the temporal replications on particular transect lines were pooled. We estimated encounter rates of

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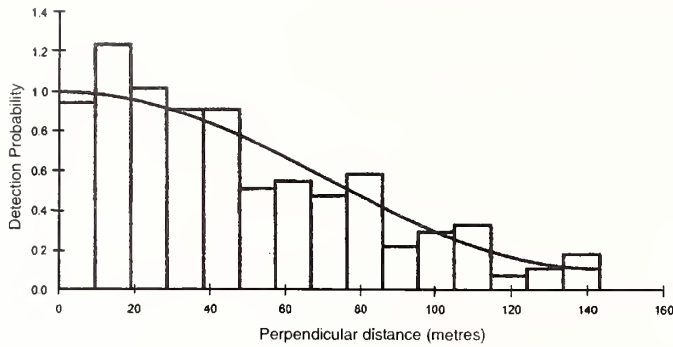


Fig. 1: Detection function model and histogram of sightings of Chital (2003). Uniform key model (KS test $D_n = 0.06$, $p = 0.37$)

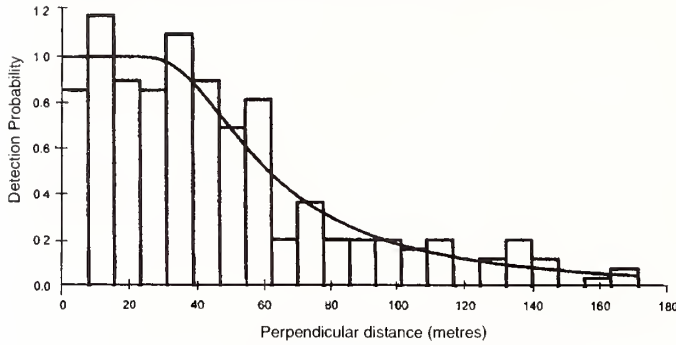


Fig. 2: Detection function model and histogram of sightings of Chital (2001). Hazard rate key model (KS test $D_n = 0.03$, $p = 0.95$)

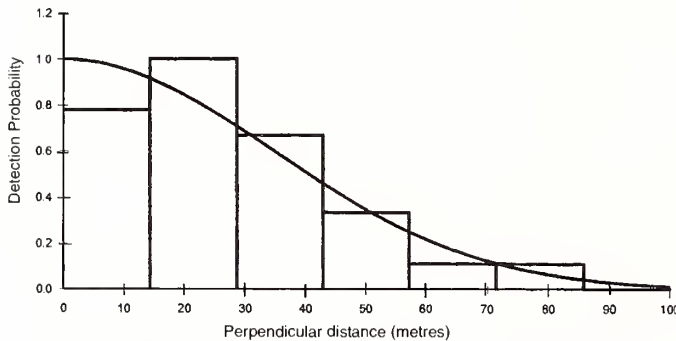


Fig. 3: Detection function model and histogram of sightings of Chital (2000). Half normal key model (KS test $D_n = 0.12$, $p = 0.82$)

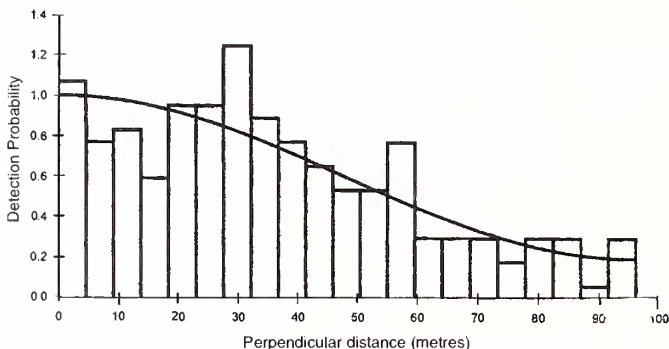


Fig. 4: Detection function model and histogram of sightings of Sambar (2003). Uniform key model (KS test $D_n = 0.07$, $p = 0.23$)

Tiger prey as n (clusters seen)/ L (total length traversed) for comparing the sampling efficiency. Appropriate models were selected from half-normal, uniform key and hazard rate based

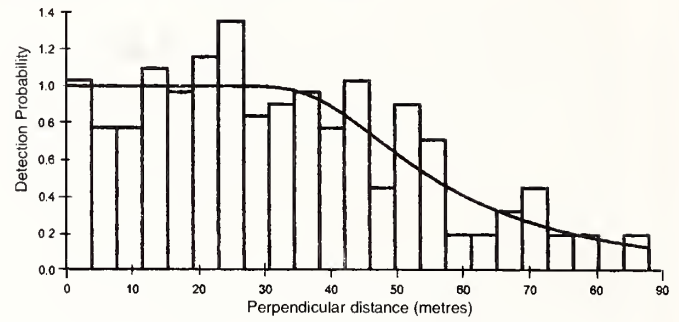


Fig. 5: Detection function model and histogram of sightings of Sambar (2001). Hazard rate key model (KS test $D_n = 0.04$, $p = 0.89$)

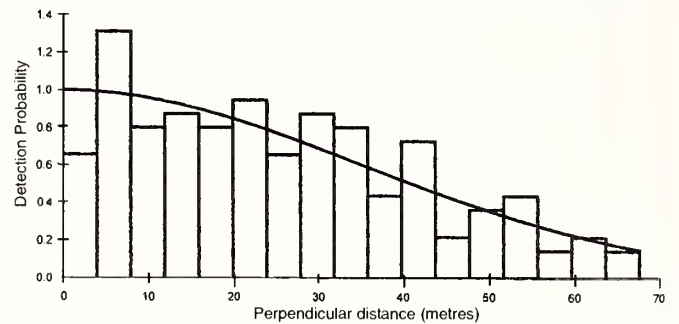


Fig. 6: Detection function model and histogram of sightings of Sambar (2000). Half normal key model (KS test $D_n = 0.04$, $p = 0.99$)

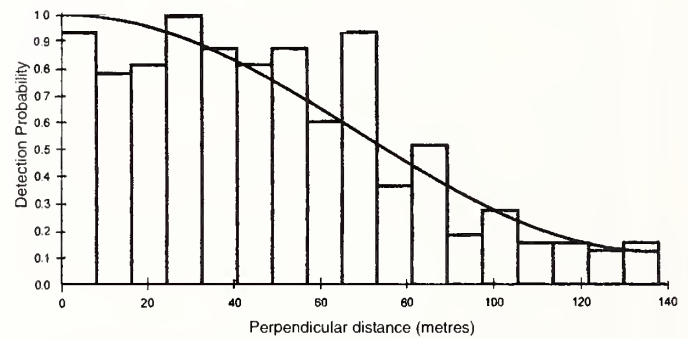


Fig. 7: Detection function model and histogram of sightings of Nilgai (2003). Uniform key model (KS test $D_n = 0.05$, $p = 0.38$)

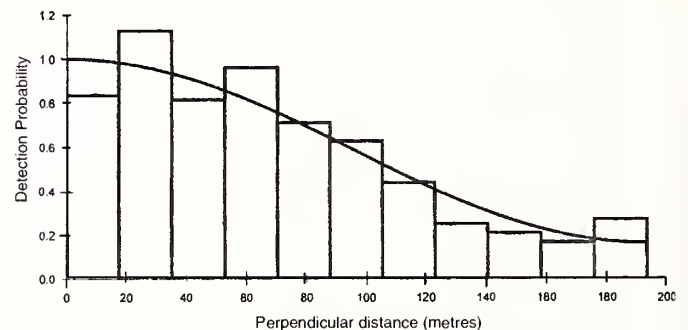


Fig. 8: Detection function model and histogram of sightings of Nilgai (2001). Uniform key model (KS test $D_n = 0.06$, $p = 0.23$)

on minimum Akaike Information Criterion (AIC) values for each year (Figs 1 to 9). Each of the individual species and their respective year's data were used separately to model

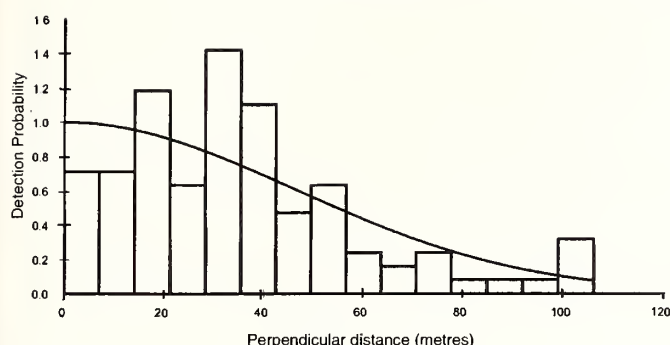


Fig. 9: Detection function model and histogram of sightings of Nilgai (2000). Half-normal key model (KS test $D_n = 0.01$, $p = 0.29$)

this detection function. Cluster sizes were estimated using Size-bias Regression method by regressing the natural log of the cluster size against the estimated probability of detection at distance x , $g(x)$. The Kolmogorov-Smirnov test was used to test how well our data fitted different models. Histograms were also scrutinised to understand how our data were behaving with respect to the assumptions of the Distance Sampling methodology.

In tropical forests of the subcontinent, ecological conditions change drastically over time and space, and this can affect animal distribution and detection (Thomas *et al.* 2002). After the monsoon (July to October), visibility in forest habitats gradually increases as the long dry season progresses and leaves fall. Loss of foliage makes it easier to detect animals, and they can be sighted from longer distances. In addition to this, changes in group size across seasons is expected to affect the encounter rate of groups of animal. Moreover, during peak summer ungulates congregate near water holes, resulting in a clustered spatial distribution. Therefore, we pooled the 2000 Distance Sampling data bi-monthly to estimate detection functions for each group separately. Changes in encounter rates, group sizes and sighting distances and their likely effects on density estimates were analysed.

To compare seasonal and morning-evening estimates obtained using distance software, one factor ANOVA was used with the available estimates and respective standard deviations (Zar 1984). The technique is valid for such comparisons since different detection functions are estimated for each group compared, and this makes the estimates independent. Changes in other parameters, such as seasonal group size and detection function were tested using one factor ANOVA. Separate detection functions for the morning and evening data sets of the 2001, 2003 and 2005 surveys were estimated. Trends were tested with the help of the maximum R^2 value and with Student's t -test for testing the significance of a regression.

RESULTS

Line transect sampling

In the monthly surveys of 2000, the total length walked was 233.6 km, and 339 animal groups were sighted. In the 2001, 2003 and 2005 surveys, the total length walked was 520.7, 466.06 and 214 km respectively. The total number of animal groups seen was 1,014 during the 2001 survey, 1,023 in the 2003 survey and 520 in the 2005 survey.

Encounter rates of all the prey species varied significantly between the two-month groups (Chital²⁰⁰⁰: $F=3.538$, $p<0.05$; Nilgai²⁰⁰⁰: $F=7.494$, $p<0.001$; Sambar²⁰⁰⁰: $F=5.049$, $p<0.005$). The encounter rates of most of the prey species of Tigers found in Panna Tiger Reserve reach the highest level during February and March (Fig. 10). We used Multiple Covariate Distance Sampling (MCDS) to incorporate the seasonal changes in the detection function. The data were classified into groups of two months each before analysis and these two-month groups were used as factor covariates at the time of analysis. Density estimates of the ungulates varied significantly between the two-month groups (Chital²⁰⁰⁰: $F=3.066$, $p<0.05$; Nilgai²⁰⁰⁰: $F=2.87$, $p<0.05$; Sambar²⁰⁰⁰: $F=4.031$, $p<0.01$). Assuming that the area sampled is closed for changes in population, one would not expect density to change across seasons. This variation can be attributed to either insufficient spatial sampling or actual changes in the study population, which was unlikely.

Mean group size for most of the species did not change significantly during the 2001 (15 days) and 2003 (45 days) surveys. We used Multiple Covariate Distance Sampling Engine (Thomas *et al.* 2003) to address the varying detection function using time period as the covariate. In 2001 and 2003 temporal variation in the detection function was primarily due to fire on the transect lines towards the end of both the surveys. After the fires, visibility increased and could have been responsible for the changes observed. Encounter rates changed significantly only in the case of Nilgai, in the 2003 survey, and show a gradual increase from 0.6 to 0.9 per km ($p<0.01$).

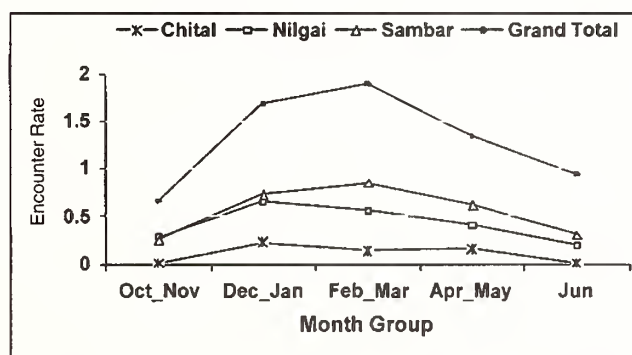


Fig. 10: Bi-monthly (pooled) encounter rates of major prey species of Tiger during the 2000 survey in Panna Tiger Reserve

During the surveys of 2001 and 2003, the encounter rates for most species differed significantly from morning to evening (Sambar²⁰⁰³: $F=5.59$, $p=0.05$; Nilgai²⁰⁰³: $F=11.35$, $p=0.005$; Sambar²⁰⁰¹: $F=9.24$, $p=0.01$), and these rates were consistently lower in the evening for all the species. Despite calculating separate detection functions for morning and evening, a significant difference in density estimates is observed for Sambar and Nilgai in 2001 and 2003 (one-tailed tests Nilgai²⁰⁰³: $F = 16.63$, $p=0.001$; Sambar²⁰⁰¹: $F=11.03$, $p=0.005$). A difference in density estimates indicates a bias associated with the distribution of animals with respect to the transect. In 2003, the same transect lines were walked in the morning and evening every fourth day to examine the effect of disturbance from repeated walking, but the results were similar to those of 2001, showing consistently lower encounter rates (and hence density estimates) in the evening. Unlike previous surveys of 2001 and 2003, in 2005 the same transect line was not walked twice on the same day (morning and evening); instead these were walked for the second time after a gap of over two days. The group size, encounter rate and other parameters such as the detection function did not vary between morning and evening counts of the 2005 survey. As a result no significant difference is observed in the densities estimated from morning and evening counts of Tiger prey in the 2005 surveys (Table 1).

Encounter rates for all the species, except Sambar, gradually declined with the length of time spent in walking the transect length in both the morning and evening surveys. In the case of Chital, there was a significant negative trend in the morning surveys ($R^2_{2001}=0.73$, $t_{2001}=3.28$, $p=0.05$; $R^2_{2003}=0.76$; $t_{2003}=4.33$, $p=0.005$) and evening surveys ($R^2_{2001}=0.88$, $t_{2001}=5.43$, $p=0.01$; $R^2_{2003}=0.88$, $t_{2003}=6.53$, $p=0.001$) of both years. Similarly, for Nilgai, the results show a significant declining trend in the morning surveys of 2003 ($R^2_{2001}=0.48$, $t_{2001}=1.91$, $p=0.2$; $R^2_{2003}=0.58$, $t_{2003}=2.87$, $p=0.05$) and in the evening surveys of 2001 ($R^2_{2001}=0.93$, $t=7.18$, $p=0.002$; $R^2_{2003}=0.26$, $t=1.47$, $p=0.2$). However, although the Sambar encounter rate declined in the morning, it increased marginally close to dusk (Fig. 11).

Density and Biomass estimation

The pooled prey abundance is estimated to be 46.32 prey per sq. km, (excluding Langur, 2003 survey). Details of the estimated prey densities and other relevant parameters are provided in Table 2. As in many of the Tiger habitats of the Subcontinent, Chital, Sambar and Nilgai dominate the wild prey population in Panna Tiger Reserve. In terms of number of animals per square kilometre, Chital is the most abundant animal. In the Reserve, the contribution of smaller prey in terms of number of animals (<25 kg and including Langur) is 30%, that of medium sized prey (25 kg to <55 kg), which includes Chital and Wild Pig, is 38% and that of large prey (>55 kg), which includes Sambar and Nilgai, is 31%. The most frequently encountered prey in the Reserve is Nilgai (Encounter rate=0.68 per km) followed by Chital (Encounter rate=0.49 per km) and Sambar (encounter rate=0.45 per km).

The ungulate prey biomass density estimated from the 2003 survey for Panna Tiger Reserve (4,057 kg per sq. km) is on the higher side for the Subcontinent. But most of the biomass (over 70%) is contributed by two prey species, Nilgai and Sambar. The contribution of Chital, the Tiger's most common and major prey throughout the Subcontinent, is only 19.69%. The contribution from other smaller prey species is less than 7%.

DISCUSSION

Due to the prevailing phenological conditions in the tropical dry forests, the encounter rate and detection function are expected to vary seasonally. The changes observed in density estimates despite applying different detection functions for each two-month group indicate insufficient sampling of the study area. We were limited to use MCDS (Buckland *et al.* 2004) because not only the detection function, but their shapes were also changing. Therefore, pooling data from surveys conducted across seasons in changing ecological circumstances may not be a reliable way to estimate densities in a tropical dry forest.

Table 1: Comparison of morning and evening density estimates of three major Tiger preys calculated from the 2005 survey in Panna Tiger Reserve

	Chital		Sambar		Nilgai	
	Morning	Evening	Morning	Evening	Morning	Evening
Density	28.33	29.61	12.51	10.77	11.27	8.80
SE	12.68	16.87	4.48	4.40	3.11	2.80
n	11	9	11	9	11	9
F		0.04		0.76		3.42
p		0.84**		0.39**		0.08**

**= no significance

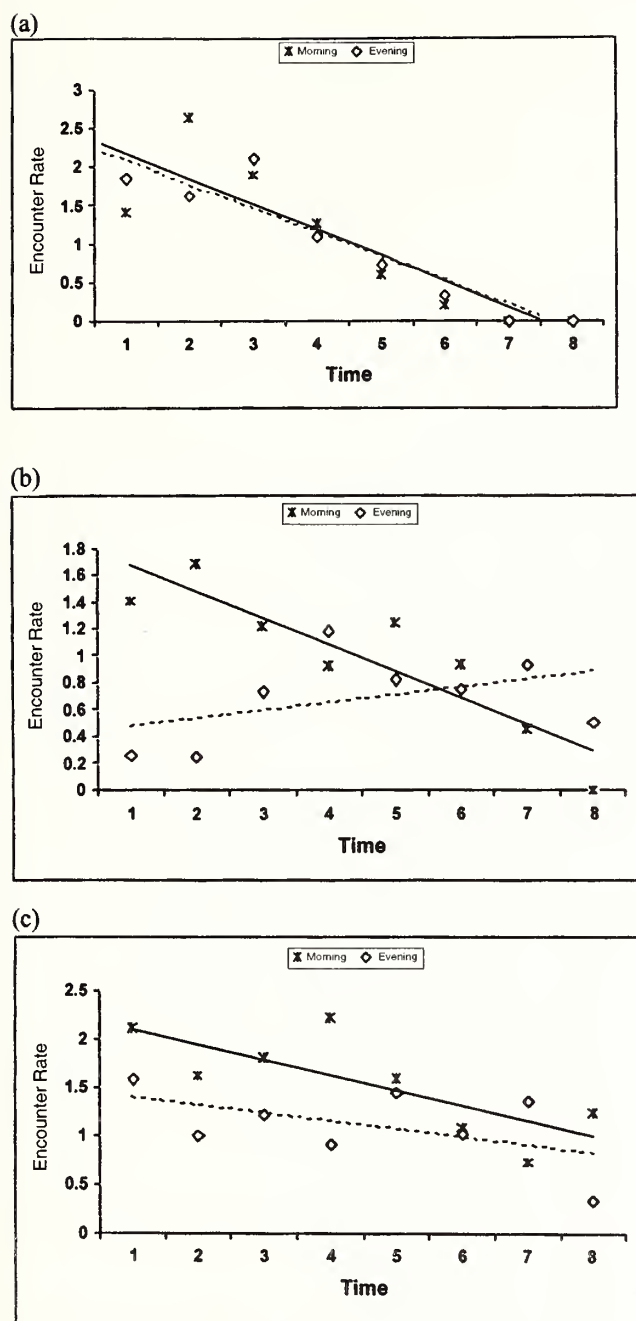


Fig. 11: Encounter rates (groups per hour) pooled for every 15 minutes time interval of three species in the morning (between 0645-0830 hrs) and evening (between 1630-1815 hrs), in Panna Tiger Reserve. Dotted line: trend for evening; continuous line: trend for morning. (a) Chital; (b) Sambar and (c) Nilgai

The highest encounter rates for most ungulate prey were obtained during February and March. During these months the group sizes were also close to the mean estimated for the year; moreover, the prey population was not clustered. Therefore, for estimation of wild herbivore populations in a tropical dry forest, February/March appears to be the most

suitable time. Walking several transect lines simultaneously and repeatedly every morning and evening maximised the number of detections for the effort (Karanth *et al.* 2002). The error associated with varying encounter rates, change in group sizes and effect of visibility on radial distance and ESW is minimised effectively when the surveys are conducted within a short time span (ranging from 15 to 40 days). Our data suffers from high CVs for a few species, which could be accredited to the small number of lines. However, an estimation of the number of lines required to bring down this CV to a reasonable range of about 20-25% gives an unfeasible number of more than 60 lines. Since the animal distribution is greatly influenced by the various habitat types in the study area, a more logical approach would be to have more lines and stratify the study area on the basis of habitats.

Disturbance from repeated walks on a line in the same day may be enough to cause animals to move away from the area resulting in consistently low density estimates for evening counts. The 2005 experimental survey results show no difference in the density estimates of morning and evening when the line is walked two days after the previous walk. This confirms that disturbance caused by repeated walking on the line was resulting in lower estimates for the evening count of the same day in other surveys. As a result, density estimates from walks repeated on the same day may be under-estimating prey populations of the area.

The activity pattern of prey species during the sampling period can be another factor which can affect density estimates. It is generally assumed that most of the animals are active in the morning and evening (Karanth and Sunquist 1992). This is a factor likely to affect sighting of animal groups and density estimates. The survey results highlight an additional point that counting animals for more than 2 hours can affect the density estimate because of the shift in animal activity patterns within a single walk. Hence, it is important to incorporate survey time as a covariate in the analysis for transects whenever the activity is expected to change within the survey.

To minimise the error encountered in the morning and evening counts of the 2001 and 2003 surveys, and the variability in group size and encounter rate in the 2000 survey, a new survey design is needed. A sampling period (as short as possible) with more randomly or systematically placed lines, which are walked once a day and repeated after a few days, can possibly minimise the errors.

The density estimate of 46.32 prey per sq. km in Panna Tiger Reserve is fairly high for a tropical dry forest of the Indian subcontinent (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Bagchi *et al.* 2003). Because mega-herbivores such as Wild Buffaloes *Bubalus bubalis*,

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Table 2: Density estimates and biomass density (kg per sq. km) of Tiger prey in Panna Tiger Reserve obtained from 2000, 2001 and 2003 surveys

Species	Year	N	D	D CV %	95% CL		Encounter Rate	Cluster size	Dg	Dg CV%	Wt in kg	Biomass density
					LCL	UCL						
Chital	2000	27	4.692	62.1	1.232	17.872	0.12	3.48	1.348	60.9	47	220.524
	2001	231	10.953	52.9	3.659	32.784	0.45	3.92	3.096	52.5		514.791
	2003	229	16.671	51.9	5.461	50.899	0.49	6	3.094	51.3		783.537
Sambar	2000	140	18.738	34.9	8.455	41.527	0.6	2.61	7.187	34.2	134	2510.892
	2001	240	8.773	37.2	3.964	19.419	0.47	2.3	3.97	36.9		1175.582
	2003	212	10.355	34.1	4.873	22.004	0.45	2.62	3.955	33.7		1387.57
Nilgai	2000	102	11.374	29.1	6.14	21.069	0.44	3.14	3.625	26	125	1421.75
	2001	307	6.301	37.2	2.836	13.998	0.6	2.72	2.671	37		787.625
	2003	316	13.112	26	7.445	23.091	0.68	2.98	4.403	24.5		1639
Four-horned Antelope	2000	31	2.975	31.9	1.55	5.713	0.13	1.61	1.845	29.5	21	62.475
	2001	106	3.952	19.2	2.621	5.958	0.21	1.23	3.327	19		82.992
	2003	78	2.702	20.6	1.739	4.198	0.17	1.22	2.218	20.2		56.742
Wild Pig	2000	6	Data set too small to estimate density					32	NA			
	2001	39	1.367	46.5	0.543	3.441	0.08	3.28	0.584	42.6		27.34
	2003	19	1.511	57.8	0.493	4.627	0.04	4.05	0.373	52.1		30.22
Chinkara	2000	24	2.301	50.3	0.763	6.94	0.1	1.88	1.227	49.4	20	73.632
	2001	52	0.913	42.1	0.381	2.188	0.1	1.62	0.723	41.6		29.216
	2003	81	1.979	45.5	0.735	5.324	0.17	1.81	1.09	45.1		63.328
Langur	2000	40	25.314	37.8	10.94	58.574	0.17	11.23	2.255	36.4	9	227.826
	2001	142	20.689	26.7	11.756	36.412	0.28	8.22	2.517	25.6		186.201
	2003	62	13.909	0.189	9.476	20.417	0.13	11.55	1.204	16.6		125.181

N = number of detection; D = density of animals per sq. km; DCV = coefficient of variation density; 95% CL = 95% confidence interval; Dg = group density per sq. km; Dg CV = coefficient of variation of group density; Wt in kg = average weight of the species; LCL = lower confidence limit; UCL = upper confidence limit

Rhinos *Rhinoceros unicornis* and Elephants *Elaphus maximus*, which contribute very little to the diet of the Tiger, are absent from a large part of the tropical dry forest, they are excluded for comparison of the prey populations (Table 3) based on this study, and Karanth and Nichols (2000). Biomass densities from these other Tiger habitats indicate that, on average, medium sized prey (46.64%) and large prey (52.27%) contribute almost equally to the prey availability. Interestingly, in terms of number of animals, medium sized prey, such as Chital, Wild Pig and Hog Deer contribute, on average, over 70% of prey availability (Table 3). In contrast to this, in Panna Tiger Reserve, the contribution by Chital and other medium prey to the prey population is small, both in term of biomass density (21.26%) and the number of animals (39.24%).

The low abundance of Chital, one of the Tiger's major preys, could be an important factor in the Tiger ecology in Panna. Being the only grazing wild herbivore (Eisenberg and Seidensticker 1976; Putman 1988; Khan *et al.* 1996), the Chital is particularly and highly susceptible to the grazing pressure of domestic livestock populations (Khan 1996; Jathanna *et al.* 2003). A large population of over 9,000

domestic cattle within Panna Tiger Reserve and extensive accidental fires in the past could be the factors limiting the Chital population here. Chital prefer grasses despite their low nutritive value even during the dry summer months (Khan *et al.* 1996). Dry season fires are devastating in Panna, completely eradicating grasses from the burnt areas. In the recent past, rehabilitation of three villages and intensive fire

Table 3: Biomass density (kg per sq. km) and density (animals per sq. km) of medium and large Tiger prey in different Protected Areas of the Indian subcontinent, (Large prey = Sambar, Swamp Deer, Nilgai; medium prey = Chital, Hog Deer, Wild Pig)

Important tiger habitat	Biomass Density (%)		Animal density, medium prey
	Large prey	Medium prey	
Pench NP ¹	41.08	58.91	81.66
Kanha NP ¹	18.76	80.81	91.09
Kaziranga NP ¹	69.85	30.14	70.91
Nagarahole NP ¹	56.13	44.13	73.91
Ranthambhore NP ¹	54.76	44.59	69.3
Panna NP ²	73.08	21.26	39.24
Average	52.27	46.64	71.02

¹Karanth and Nichols 2000; ²This year

protection measures have created extensive grasslands and restored them as suitable habitats for Chital. As a result the Chital population is recovering, mainly in areas recently made free from human pressure, as has been documented in other protected forests of the Subcontinent (Karanth and Sunquist 1992; Khan *et al.* 1996).

The Tropical Dry Forest of Panna supports ungulate populations that have evolved in different environments, one in open habitats, and the other in forest mosaics. Nilgai and Chinkara represent prey populations partial to open habitats whereas Sambar and Chital are forest and forest-edge dwellers (Schaller 1967; Prater 1988; Eisenberg and Seidensticker 1977). Because the Tiger has evolved as a specialised forest-edge predator following the cervid radiation in Asia (Sunquist *et al.* 1999), its survival and hunting strategies are more cued to cervids than other prey species that occupy the open habitats, such as Nilgai. Therefore, in dry forests, a high abundance of prey in open habitats (such as Nilgai) does not entirely translate into Tiger prey availability. Thus, an appropriate balance of prey species needs to be maintained in order to support healthy Tiger

populations. Density estimates of Tiger prey from Pench, Ranthambhore, Gir and Panna indicate that tropical dry forests — the largest Tiger habitat in India (Wikramanayake *et al.* 1998) — can support a fairly high prey biomass, provided the habitat is adequately protected.

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